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LINEAR MOTOR HAVING PROGRESSIVE MOVEMENT CONTROL

The present invention relates to a linear motor having progressive movement control according to the definition of the species in Claim 1, in particular a linear motor having a plurality of secondary components (moved components), the linear motor preferably being used in processes of industrial automation.

The U.S. patent 5,965,963 describes a linear motor made up of a secondary component and a primary component (stationary component), the secondary component implementing the triggering of the coils integrated in the path with the aid of position-sensing sensors such as Hall-effect sensors (Fig. 1B, Fig. 3), which are mounted along the path, and with the aid of a magnet situated on a secondary component. This invention has the disadvantage that the mechanical system for sensing the position becomes increasingly more and more complex as the number of secondary components is increasing, reaching its limit with four to six secondary components (Fig. 10). Moreover, it is more difficult to expand an existing path since the implementation of rail and secondary component depends on the number of secondary components. Also, the already existing control has been configured for the specific application case, and a modification of the system configuration requires considerable time and technical effort. The concept of using position sensing also has the disadvantage that the generated signal will be falsified if even a single sensor breaks down, so that an eventual collision or a malfunction is thus virtually preprogrammed. In addition, the wiring required for analyzing all sensor signals is considerable. In practice, this drastically increases the susceptibility to faults, in particular under adverse circumstances.

U.S. 5,023,495 shows a d.c. linear motor, which theoretically has an infinite number of secondary components that can be controlled independently. Here, the position is sensed with the aid of, for instance, permanent magnets affixed on the secondary component whose magnetic field is sensed by sensors (Fig. 7, reference numerals 8, 46) mounted on the primary component. No further description of the control of the secondary components is provided; the teaching essentially encompasses the mechanical configuration of primary and secondary component as well as their cooperation. In this case, it is disadvantageous that an external control would have to assume the entire process coordination and only straight movement paths can be realized.

The laid-open document U.S. 0,180,279 A1 shows a modular system made up of linear motors. Figures 17 through 21 illustrate the flexibility of the disclosed invention based on the realization possibility of movement paths that, theoretically, have any conceivable configuration. In one illustrated potential realization form, the secondary component includes a battery-powered signal-processing device (Fig. 5), which carries out the position sensing by remote control via radio and reports it to a central control unit. However, the configuration of the secondary and primary components is similar to the design disclosed in U.S. 5,965,963 and hence has the same disadvantages. Here, the movement is controlled by a central motor controller, which communicates with module controllers via a network and therefore controls and administers all secondary components. With the aid of the received position data, the controller network must calculate all information relevant for the movement control such as acceleration, speed, shear force, and trigger the coils accordingly. The control of the secondary components becomes more complex with each increase in the

number of secondary components since the position must be detected for every secondary component, and the corresponding coils on the path formed by the primary components must be switched in such a way that all secondary components move completely independently of each other and collisions are prevented. In addition, to avoid losses, only the coils that are directly underneath the secondary component should be triggered.

U.S. 6,502,517 and EP 580107B1, which both relate to magnetic levitation systems, also should be mentioned in this context. U.S. 6,502,517 discusses the mechanical and electrical aspects of such a system realized with the aid of a linear motor and proposes a design approach for the non-contacting transmission of electrical energy for electrical components on the floatingly supported secondary component. The contents of EP 580107B1 likewise describes a levitation system, the focus in this case being on, among others, the control of the air gap as a function of the loading of the suspended component. For this purpose, the moved component includes a control unit, which permanently monitors the air gap and initiates appropriate countermeasures as soon as the required setpoint changes. The essence of the distance control are electric magnets, which are mounted on the moved component and via whose current supply the path distance is able to be adjusted.

It is the objective of the present invention to design a linear motor of the type mentioned in the introduction in such a way that, especially when using a multitude of secondary components, far-reaching modularity and flexibility are ensured, in particular with respect to different applications or machine configurations, this being accomplished with a minimum of equipment and software. This objective is achieved by the features of Claim 1. In order to be able to offer a modular system that is rapidly and easily adaptable to a wide

variety of problem definitions, it is necessary that the number of secondary components is not restricted, so that the user can set up all types of conveyor systems having freely defined paths. One part of the required movement controller is structurally provided on the secondary component in such a way that the secondary component itself assumes a share of the computer-intensive movement control. This significantly reduces the load on a possibly provided controller. The secondary component thus becomes a practically autonomously acting, intelligent unit, which, from an input of setpoints such as path inputs, and through the independent determination of actual values such as absolute position data, for instance, is able to initiate all actions for progressive movement on its own. In this way, a local triggering of the required coils is achieved in a simple manner, the setpoint then being used only for the coil controllers that are required to drive the secondary component in the desired direction or at the desired speed, etc. Such a movement control is practically a decentralized version or at least a partially decentralized version of the control, the required movement control loop being split according to the present invention.

The secondary component is provided with an energy supply for this purpose. This energy supply of the secondary component feeds a signal-processing device, which has a movement controller or progressive movement controller and is structurally situated on the secondary component. The movement controller or progressive movement controller hence is part of the overall movement control of the linear motor. For instance, a positional setpoint or a velocity setpoint or the like (see further down) also may be generated by a centralized or decentralized controller, such as a stationary controller, and transmitted to the secondary component. From this, the secondary component could generate a setpoint current, which is used to trigger coils mounted on the primary

component or which is utilized as input signal of the coil controller.

This (current) setpoint is generated in the signal-processing device and is relevant for the triggering of the coils, i.e., for the physical conversion of the desired movement. Here, relevant means that the physical motion resulting from the triggering of the coils and from the field resulting therefrom takes place in accordance with the setpoint generated in the signal-processing device.

It is essential in this context that the setpoint is transmitted to a stationary coil controller. This is done via a setpoint interface provided according to the present invention.

The setpoint interface is used to transmit the setpoint from the secondary component, which usually is the driven component, to the stationary coil controller. The setpoint is then used for the commutation of the coils according to the conventional control of a linear motor. The required wiring for transmitting the setpoint or for triggering the coils, for instance, is relatively simple according to the present invention; in contrast to a centralized or partially centralized controller with a likewise centralized or partially centralized generation of the setpoint, the required wiring according to the present invention is not based on the number of provided coils and may therefore be implemented very inexpensively and efficiently even if very long paths or a multitude of secondary components are/is involved. In the extreme case, a setpoint transmission from a centralized or decentralized control architecture to the coils of the primary component may also be dispensed with entirely.

Using the present invention, it is possible for the first time to set up any type of path with a very low investment in hardware and wiring.

In this sense, the logic, i.e., "intelligence" that needs to be provided in the primary component for each individual coil is practically non-existent or reduced to a minimum. This also applies to the drives of the corresponding coils. The detailed development of the power components of the coils will be discussed in greater detail in the further course of the application.

Using the present invention, applications are conceivable which function completely without external control signals in that the secondary component is equipped with a processor and a memory and the memory includes the entire movement sequence in the form of program code and/or position data. Traveling the predefined position inputs would require position sensing, which is conceivable in the form of an active device energized via the energy-supply interface and situated within the signal—processing device, or which is situated separately therefrom on the secondary component. This device senses the position of the moved secondary component relative to the path formed by the primary component and works in a completely autonomous manner. For position sensing, a raster affixed on the primary component along the path would suffice, which is scanned via a transceiver mounted on the secondary component and analyzed by a simple counter, for example. The position sensed in this manner, which may be relative or absolute, is compared with the stored position data and thereby allows a precise progressive movement control. For instance, the sensing of the absolute position of the secondary component is realizable by providing each modular path section with a unique marking, i.e., a marking that is used only once in the overall path. This could be a path-segment marking using

binary code, which is detected by the scanner and analyzed. Using the combination of path-segment marking and the sensed relative position within a path segment, it would be possible to calculate the absolute position in the overall path. In the event of a system failure or a derailment of the secondary component, the re-initialization would also be simplified considerably since the homing (traveling of the path for repositioning) that is common in such a case is greatly simplified in this way. The secondary component would thus be able to travel any given movement path without external position inputs, such path being programmable and thus modifiable by changing the program code and/or the position inputs. This adaptation of the progressive movement inputs would be possible even during operation, by memory media able to be plugged in, or by using a suitable data interface. A virtually unlimited application spectrum opens up as a result.

For a further increase in the flexibility, it is proposed that the secondary component obtain movement-state information, preferably according to the velocity and/or acceleration and/or the relative or absolute position, and/or the shear force, via at least one sensor interface, from a movement-state sensor which is mounted in the region of the primary component. Having the movement-state information relating to the secondary component at its disposal, the movement controller on the secondary component possesses a high degree of "intelligence". The secondary component then has the information of its movement state available virtually at all times, so that movement sensing, for the purpose of collision monitoring, for instance, may be implemented on the secondary component. Furthermore, such movement-state information also could be used for a preprogrammed position control. When the secondary component receives these movement setpoints, a very rapid movement control is ensured on the secondary component

itself, which takes a wide variety of parameters into account similar to a conventional control.

The present invention realizes practically the entire variability and basic bandwidth of a conventional centralized or partially centralized control architecture in the simplest fashion if the secondary component receives movement setpoints from at least one control device, preferably according to the velocity and/or the acceleration and/or the relative or absolute position and/or the shear force, via at least one control interface mounted in the region of the primary component.

The task of the control device then consists (preferably only) of controlling or synchronizing - for instance as stipulated by an industrial process as outlined below - the movement of a secondary component or a plurality of secondary components, as mandated by the underlying required process such as a manufacturing process. The control device as well as the communication between the control device and the secondary component(s) is considerably simplified in this manner since the control device no longer has the burden of carrying out the aforementioned movement control processes. As a result, complex and predefined paths and movement inputs may be realized and, in particular, also a plurality of secondary components be controlled in a synchronous manner according to the inputs of even complex processes.

If at least one control device is set up in a decentralized manner and includes control modules disposed in the region of the primary components, the advantages of the present invention are combined with a decentralized controller architecture. This reduces the complexity of the overall system, so that more complicated application cases than in the related art can be realized by distributed computer outputs

and, in particular, distributed "intelligence" of the controller(s).

The possibilities of realizing different processes as well, or of programming such processes in the preliminary stages are increased in that the control device administers specific features of at least one secondary component, preferably identifying features, for the control thereof and implements a transmission and reception via a control interface. Set-up processes or start-up processes, for instance, may be implemented in a much simpler manner if such specific features are available. When a process is started or resumed, specific, control-relevant features of a secondary component, a plurality of secondary components, or of all secondary components situated in a path section may be queried and used to initialize the process. During the process, the control device may utilize such specific features to administer or handle the particular process. To accomplish this, the specific features are transmitted from the secondary component to the control device via a control interface. It is therefore preferred if the control interface has a bidirectional design (according to Claim 3 in conjunction with Claim 5). The specific features (in particular for the start-up or the resumption) may be technical features of the secondary component that are relevant for the control; as an alternative or in addition, however, these may also be features that are predefined for each secondary component in advance.

According to Claim 6, the specific features of the secondary component, preferably the identifying features, are also used in the signal-processing device of the secondary component itself. This would be useful, for instance, for identifying technical data of the secondary component during the control, such as parameters that are relevant for the movement control.

This considerably broadens the utilization spectrum of a linear motor according to the present invention and may simplify the control at the same time.

To allow an unequivocal control and identification of each secondary component beyond the technically required data, Claim 7 proposes that at least one identifying feature be a unique address that addresses at least one secondary component. Unique means that the particular address is predefined only once for each secondary component and thus is unambiguous.

To reduce the present invention's susceptibility to faults and to limit the service requirements, it is suggested that the control interface or the sensor interface or the setpoint interface be implemented as non-contacting interface. This dispenses with the corresponding wiring, so that the mechanical limitations of the movement that are usually associated with the wiring are likewise avoided or reduced. The system's susceptibility to faults, for instance as a result of cable fracture, which may be more likely with increased by mechanical loading, is reduced. The design is simpler and also more cost-effective overall due to the reduced wiring complexity, and the required servicing of the wiring and plugs, for instance, is avoided or reduced as well.

Various embodiments of non-contacting interfaces are possible in this context; the choice of the interface technology or interface physics is based on the data-transmission rate to be realized and the type of data to be transmitted, and also on the specifications of the particular interface.

To set up an interface having a relatively high data-transmission rate, it is recommended that at least one of the interfaces be embodied as infrared interface and that the

sensor system optionally be shielded from the environment in a fluid-tight manner by a transparent seal. Such an infrared interface allows high data rates to be modulated due to the high frequency of the infrared light. The interface may have a unidirectional and/or a bidirectional configuration. For example, it would be conceivable that the entire region of the primary component traveled by a corresponding secondary component is irradiated by one or a plurality of infrared sources. Each secondary component communicating via the infrared interface must then be equipped with at least one infrared receiver, which converts the infrared signals and makes them accessible to the movement controller of the secondary component. Such an infrared interface between the primary component and the secondary component also could be implemented in the form of a rail, the infrared transmitter and infrared receiver being situated in distributed fashion parallel to the path route in the longitudinal direction, in accordance with the geometry, so that a continuous and largely uninterrupted transmission is ensured also when the secondary component is moving relative to the primary component as required by the movement of the secondary component. For this purpose, the corresponding transmitters and receivers are preferably integrated in the rail and positioned in encapsulated form in such a way that incident light and also contamination of the infrared sensors or transmitters is largely avoided. A practical solution would be to develop the control interface as a field bus, which ensures that the position data etc. is transmitted to the secondary component or to each secondary component virtually in real time.

To develop a non-contacting interface that has the lowest possible susceptibility to faults and high functional reliability, it is proposed that at least one interface be embodied as inductive interface. Such an inductive interface is largely indifferent to contamination, incident light or

other external influences. In addition, an inductive interface may be designed to be completely isolated from the environment, for instance with the aid of a tight cover. Such an interface could also be designed as an absolutely watertight and fluid-tight interface by casting it of an appropriate material such as epoxy resin. This is relevant especially with packaging machines or industrial applications where heavy contamination is to be expected.

The same applies if at least one interface is designed as radio interface. Such a radio interface has the additional advantage that higher transmission rates, such as required for a field bus, for example, are realizable as well. Moreover, practically any distance may exist between transmitter and receiver in this case, so that the flexibility in use is increased considerably.

To produce the interfaces in a more cost-effective and less complex manner and in order to utilize the available interfaces as efficiently and completely as possible, it is proposed that at least two interfaces, preferably the control interface and/or the sensor interface, and/or the setpoint interface, be combined into at least one unified interface.

To adapt the setpoint to be transmitted to the available data rate in the transmission of the setpoint information, it is proposed that the setpoint generated by the signal-processing device belong to a single setpoint category. This means that an individual setpoint of a specific, predefined type will be generated by the signal-processing device during operation.

The setpoint generated by the signal–processing device may be a position setpoint. In this case, a corresponding signal processor, which forms a setpoint for the coil triggering from the position setpoint, would have to be provided on the

primary component. This reduces the required data rate in the data transmission since such a position setpoint requires a lower data-transmission rate than a current setpoint, for instance. The same generally applies if the setpoint generated by the signal-processing device is a speed setpoint. The linear motor is preferably designed in such a manner that the setpoint generated by the signal-processing device is a current setpoint or an acceleration setpoint. A relatively large part of the required logic circuit will then be situated on the secondary component, so that the complexity of the circuits in the primary component is very low. In particular when a long path is involved, this has the advantage that the resulting overall complexity of the logic circuits is reduced drastically. In the same way, the signal-processing device also may generate a voltage setpoint, resulting in an higher demands on the bandwidth of the setpoint interface.

If sufficient transmission capacity or bandwidth is available, the possible operation bandwidth may be increased in that the setpoint generated by the signal-processing device represents a combination of setpoint categories as recited in Claim 14.

The secondary component requires an energy supply for the movement controller. It is preferred that the energy supply of the signal-processing device of the secondary component is provided by a single type of energy source, since this simplifies the incorporated energy supply.

This applies all the more if the energy supply of the signal-processing device of the secondary component is an energy source mounted on the secondary component, preferably a chargeable accumulator or a non-chargeable battery or a solar-cell system. Such an energy source will already be sufficient for a signal-processing device according to the present invention since the energy requirement is relatively low.

To ensure a permanent, uninterrupted energy supply of the secondary component it is proposed that the energy supply of the signal-processing device of the secondary component be an inductive energy interface, preferably an induction coil, which takes up electrical energy in a non-contacting manner via at least one coil, which is stationary relative to the primary component.

For a compact system and a reliable as well as permanent energy supply, a pick-up mounted on the secondary component and in contact with the primary component may conduct the energy to the signal-processing device, preferably via a sliding contact or a roller contact.

Finally, the energy for the signal-processing device of the secondary component may also be conveyed to the secondary component by a cable connection. Such a cable connection would constitute an inexpensive alternative solution. Moreover, a cable connection largely precludes interference effects; this is advantageous especially when relatively low voltages/currents are transmitted, so that malfunctions by superpositions are preventable in this manner.

Combinations of the aforementioned energy sources are naturally possible as well; for instance, an accumulator would be conceivable as backup energy supply, while the energy during operation is supplied by an inductive, sliding, rolling or cable connection. The accumulator would then be charged by the "operating energy source" and could assume the power supply if need be.

Non-contacting energy transmission and/or data transmission means are preferably provided according to the present invention. In order to ensure a compact design and the most

reliable and faultless transmission of the individual signals, it is therefore proposed that, for the non-contacting transmission of energy and/or for the non-contacting transmission of data, the means of the secondary and primary components communicating with one another be situated opposite each other during operation, on the sides of the secondary component and primary component facing each other.

A more precise movement is realizable by the triggering of individual coils, i.e., in such a way that individual coils on the primary component are positioned next to each other along the movement path of the secondary component, and the coil controller supplies energy to at least one individual coil.

It is preferred here if the secondary component is moveably supported on the primary component with the aid of a rail having at least two tracks. A support on two tracks is easily possible with the aid of the present invention since it will leave enough free space to realize the required interfaces. Due to the flexibility of the present invention, such support on two tracks is easy to implement mechanically as well. Due to the two-track support, the mechanically stable guidance of the secondary component is realized in the region of the primary component. The rails and the associated guideways may be provided on the side of the secondary component and also on the top or bottom.

A roller bearing may be provided in such a way that the secondary component has at least three rollers, two rollers being assigned to a shared track, and a third roller being assigned to an additional track. This ensures reliable guidance on the rails or the rail guides even when traveling along a curve, in particular a curve having different radii.

To this end, it is also proposed that the particular roller situated opposite the two other rollers be flexibly supported on the secondary component. In curve travel, the third, flexibly supported roller may then comply with the particular curve constraint by giving way as required or adapting its position to the posed constraint. In addition, the flexible support of the roller ensures even cornering.

The principle expressed in Claim 27 is utilized to improve the coil trigger device in such a way that the required hardware is relatively minor and the susceptibility to faults reduced. Due to the fact that each trigger element is embodied as half-bridge, a multitude of components is saved compared to an H-bridge, for instance. The savings are essentially proportional to the specific length of the path. In particular in the case of complex processes and large machines, this may result in considerable material savings and simplification of the circuits. Especially with industrial machinery, a loss of production causes considerably expense. Since much fewer components are used overall, the likelihood of a malfunction is reduced drastically. The savings in components could be reinvested, for instance by using undoubtedly more expensive, but therefore more reliable and less fault-susceptible components. Given today's market prices, such components (IGBT's) would still cost less, yet provide a considerably longer service life and better reliability.

The aforementioned advantages can be multiplied by the number of coils installed in each case. It is therefore proposed that a number n of control elements designed as half-bridges be connected to an individual coil of n affixed on the primary components. Since the half-bridges are realized in a redundant manner, at an expense that is comparable to a corresponding H-bridge, a standby controller would be

available in case of a malfunction. In view of the consequences of a production loss, the attendant expense is clearly justifiable.

In addition to the objective mentioned in the introduction, the present invention is also based on the objective of implementing an industrial machine, in particular for automated lanes, which includes an industrial process, specifically for flat stocks, packaging and tools, the process involving a linear movement executed along a predefined path by a linear motor including a movement controller, having at least one secondary component and at least one primary component having field-generating coils in concentrated or overlapping windings, in such a way that it is able to be used for a wide variety of application fields and for a multitude of different configurations, relatively high accelerations and high rigidity of the movement being realizable as well, if need be.

This objective as well as the objective mentioned in the introduction is achieved by the features of Claim 29.

Such a machine provides all the advantages already mentioned in the introduction in connection with Claim 1. However, it is precisely high flexibility and various application fields and different configurations - for instance in a product rearrangement - that are of the utmost importance with industrial machinery. As mentioned earlier, such flexibility is ensured by the present invention. In this way the linear motor, i.e., the principle of the linear motor, is for the first time made available for an industrial machine of the type mentioned at the outset, in a simple manner and up to the point of production readiness.

Due to the simplification of the control processes already described earlier, the advantages of an industrial machine are utilized in an especially efficient manner by the present invention if the machine includes a plurality of secondary components which execute a process-synchronous movement according to predefined process rules. A plurality of secondary components entails increased complexity of the associated control process. Moreover, in an industrial machine the individual secondary components must also be moved in a process-synchronous manner, i.e., be synchronized, relative to one another. This synchronization of the secondary components is implemented according to predefined process rules as specified by the industrial process forming the basis and executed by the machine. The present invention yields special advantages in this context. For instance, various processes encompassing different movements and different numbers of required secondary components may be realized at relatively low cost. Also reduced to a minimum is the expense in a start-up or refitting of the production, i.e., a change in the production, since in a refitting or start-up, for instance, a possibly existing controller is limited to the administration of the industrial process, the control processes, which may even be more complex, being carried out in a decentralized manner in the secondary components. This simplifies the corresponding control program, and thus also ensures a more rapid and reliable start-up or refitting of the machine. The control becomes more independent, or even completely independent of the hardware. In the extreme case, for instance, a control could be parameterized simply by inputting the boundary conditions and parameters that are relevant exclusively for the process. Such parameters are, for example, the paths, movement parameters of the process, number of secondary components and primary components.

Due to the reduced overall complexity as a result of the distributed intelligence, the present invention yields its advantages in a particularly efficient manner if the machine has at least five secondary components. Such a machine typically may also have considerably more than five secondary components, for instance 20 to 100 or several hundred secondary components. Due to the fact that the "control intelligence" is largely realized in the secondary component and primary component, i.e., in the components itself, the number of secondary components appears to be virtually unlimited given the processing power of today's controllers.

This allows the number of secondary components to be freely defined; depending on the process, it is limited solely by the process specifications, the geometry of the secondary components and the path design of the primary component.

A path having great variability in design is achieved by predefining the linear movement by a movement path formed by a plurality of primary components. Different primary components each having a different predefined length may be used in this context, so that a path may be set up in the manner of a kit, for instance. Such a kit may include straight or curved primary components, which are then freely selectable in accordance with the envisioned path. In particular, straight pieces having different lengths, and curved pieces having different overall lengths and different radii of curvature may be present. Thus, most if not all of the industrial processes currently in use in the mentioned branches of industry are covered. In particular individual elements preferably having different rising or falling slopes may be provided as well, so that, overall, a path in a machine may be implemented on different levels.

It is preferred in this context that a higher-order process controller monitors and controls movement sequences. Such a higher-order process controller has the aforementioned advantages; in addition, if a plurality of available secondary components is present, the process controller guards against a collision of secondary components by a programmed collision protection.

The process controller may also implement an initialization of all secondary components during start-up or in the event of a fault, or in a production conversion and a production resumption. Under these circumstances, the reproducibility of the process to be implemented is easily ensured at all times, all advantages of the present invention being available.

To eliminate or reduce transition faults between two primary components and to ensure continuity of the production sensing, it is proposed that the process controller monitor and control the transition of the secondary components between two primary components.

The packing industry, in particular, makes many different demands on the path geometry and the movement characteristics of secondary components. Therefore, it is especially preferred if a machine for the packaging of goods, in particular food items or luxury food stuffs, is involved. The present invention covers all types of packaging machines: foil-seal machines, stretch-film bundlers and shrink tunnels, tray and wrap-around packagers for carton packaging, etc.

To prevent soiling or malfunction of the machine, it is proposed that its components be waterproof or splash-proof.

The present invention has virtually no limitation with respect to the path geometry. For instance, the entire path or

portions of the path may be arranged horizontally/vertically on top of one another, and a movement may take place into a horizontal plane, between different horizontal planes, or in a vertical plane. Even a combination of paths having an autonomous design may be used together in order to find a solution for an automated process.

In this way the application spectrum of the technology according to the present invention is open to practically all branches of industrial automation requiring a linear movement. A production line having one or a plurality of tool machines, for example, requires especially complex systems. It is therefore proposed that the subfunction of a tool machine is involved or the function of an automated lane or conveyor lane.

The simplicity in terms of control engineering, the high rigidity and excellent positioning accuracy of the present invention come to the fore in particular when a printing machine is involved. This might be a sheet-fed printing machine, where the linear path would be provided for the conveyance of sheets. The sheet to be conveyed in linear fashion is clamped between two adjacent tracks by two adjacent secondary components traveling along these paths.

Description of the Figures

All Figures 1 to 3 are schematized or roughly schematized drawings and are used solely to illustrate the written explanations. Figure 1 shows a cross-section of a linear motor configured according to the present invention. Figure 2 illustrates the commutation of the coils via the setpoint. Figure 3 shows the triggering of an individual coil in detail. Figure 4 represents the schematized illustration of an industrial machine based on the present invention. Figure 5

shows a possible implementation of the support of the secondary component on the primary component.

The linear motor shown in Figure 1 is made up of a secondary component 7 and a primary component 8. The illustration is merely an example; for reasons of clarity, it shows only a single secondary component 7 in a sectional view. Primary component 8 forms a route preferably traveled by a plurality of secondary components 8 simultaneously.

Control connection 13 ensures the connection to a controller, which is set up in a centralized or decentralized manner and implements the coordination of the movement process or of an entire industrial process. Control information is transmitted to corresponding and oppositely situated control interface 5 of the secondary component in a non-contacting fashion via control interface 5 on the primary component, which could be implemented as inductive, bidirectional interface in the specific example. Control interface 5 of the secondary component is connected to a signal-processing device 6, which analyzes the data received from the controller and in turn possibly supplies updated movement data to the controller. Via another non-contacting interface, a movement-state sensor 12 provides position information to signal-processing device 6. These data are used by signal-processing device 6 to record the instantaneous position of the associated secondary component relative to the primary component. Energy source 11, situated on the secondary component, supplies electrical energy to signal-processing device 6 on secondary component 7, also in a non-contacting manner, the energy being required to operate signal-processing device 6. The transmission of process energy for an electric tool mounted on the secondary component, for which a cable connection, for instance, would otherwise be required, is conceivable as well. Such a tool could be welding tongs of a machine for packaging food items.

The welding tongs have the task of implementing an airtight seal of the foil in which the food items are packaged by sealing the foil ends. Field-generating device 10 could be made up of, for instance, windings mounted on the primary component, which generate a traveling field along the movement path of the secondary component. Passive magnets whose magnetic field is in reciprocal action with the traveling field are affixed on the secondary component. The cooperation between traveling field and stationary magnetic field thus causes the secondary component to be moved relative to the primary component. The triggering of a field-generating coil is implemented by coil controller 9, which receives inputs regarding the required field strength via setpoint interface 1. Setpoint interface 1 would be realizable as infrared interface, for example, which would usually handle a transmission bandwidth of approximately 16 Mbit/s. The use of an infrared transceiver as it is utilized for data transmission in personal computers or PDA's, for instance, is conceivable. The setpoint could be a current setpoint, which is directly proportional to the intensity of the magnetic field and thus to the acceleration of the secondary component. Via a fourth non-contacting interface, setpoint interface 1, the current setpoint is directly provided by signal-processing device 6 of secondary component 7. Signal-processing device 6 directly derives this setpoint from the data it obtains from sensor interface 4 and control interface 5. The data from control interface 5 might be a position setpoint from which signal-processing device 6 calculates the required acceleration and velocity as a function of the path to be traveled, and then requests the necessary traveling field strength via the current setpoint.

Figure 2 shows a plan view of a cutaway portion of a path 21 formed by primary components by means of coils triggered in a three-phased manner. Once again, for reasons of clarity, only

one secondary component 7 and only one path section 22 are shown. This secondary component 7 is able to move above path 21 in a forward and/or reverse direction along the arrows shown. A rigid support of the secondary component could be implemented by rollers and tracks, for instance; however, a magnetic levitation system would be conceivable as well. Here, the transmission of the setpoint from signal-processing device 6 of secondary component 7 via setpoint interface 1 of the secondary and primary components is implemented via a separate interface for each of the three phases, which is why three setpoint interfaces 1 have been drawn in next to one another on secondary component 7, but at a mutual offset in the direction of movement. Each of the three segment-type setpoint interfaces 1 of primary component 8 triggers a group of windings 10 in parallel, via corresponding setpoint interface 1 of primary component 8, in this way providing an in-phase current supply. It is important to realize here that only those coils are supplied with current that are actually required to drive secondary component 7, i.e., those windings that are underneath or directly in front of secondary component 7 at that point. This principle of the coil triggering as a function of the position of the secondary component effectively limits, among others, the power losses of the conveyor system.

In a 3-phase system as shown in Figure 2, a separate coil controller 9 supplies each third coil with current having an identical phase position. Here, coil controller 9 (Fig. 1; Fig. 3) is merely indicated by a transistor symbol. During the movement of the secondary component along path 21, setpoint interfaces 1 situated on the bottom of the secondary component are traveling along the path and pass their corresponding interfaces on the primary component in the process. This leads to the already mentioned commutation of the coil current in accordance with the movement progression.

If secondary component interface 1 of secondary component 7 leaves the sensing range of the interface on primary component 8, the current in the affected coils will be shut off. If the system reaches a new interface, the coil current will be activated, which then drives the secondary component in the desired direction. Using the setpoint transmitted to coil controller 9, there is the additional possibility of influencing the progressive movement, for instance so as to increase the speed or acceleration as a function of a load or for an input by a centralized control device.

Figure 3 shows coil controller 9 in the form of a schematic basic circuit diagram. A setpoint current for the triggering of the coils received from setpoint interface 1 is compared with the instantaneous actual current value 17 of the coils. This actual value is determined directly, via a measuring device 23. The result of this comparison is conveyed to a pulse-width modulator 15, which triggers a field-generating coil via two IGBT's connected as half-bridge 14. In this example, coil controller 9 is therefore made up of a comparator 16, PWM controller 15, half-bridge 14 as well as a measuring device 23. Additional components may be necessary depending on the required tasks in each case. Coil controller 9 receives the input signals from setpoint interface 1 and from actual value feedback 17. The output signal is directly used for supplying field-generating coils 10. In this case, the supply voltage of the device is a bipolar power supply characterized by power supplies 18 and 19. The actual current value is measured relative to mass 20. Additional developments for triggering the coils are conceivable.

Figure 4 shows an industrial machine 30, in particular an automated system for conveying goods 29 (boxes, any type of material) which includes a path 21 configured in the form of a "race track". Path 21 includes curve modules 31 and straight

modules 32, the modules abutting each other at transitions 33. Straight and curved path sections 31/32 are represented by correspondingly configured secondary components 8 of the linear motor according to the present invention. Path section 22 is shown once more in greater detail in Figure 2. In this example, seven secondary components are moving on path 21. Also shown are two conveyor belts 24a/b having conveyor rollers 25 and drives 27 as well as a positioning plunger 28 and a higher-order central controller 26, which communicates with the units to be triggered via data bus 35.

The system operates as follows: Central controller 26 regulates the entire process of the system and predefines the working cycle for conveyor belts 24a/b and the secondary components. It is assumed that the working cycle of conveyor belts 24a/b differs, i.e., belt 24a is operated at a different speed than belt 24b. The task of path 21 according to the present invention is to convey goods from conveyor belt a to conveyor belt b in such a way that a continuous operation is ensured, i.e., no idle time occurs or even collisions of transport goods 29. Conveyor belt 24a supplies goods 29 such as boxes, which - due to their prior acceleration and inertia and possibly a slight gradient - are conveyed with the aid of transport rollers 25 to a secondary component 7 appropriately positioned by central controller 26. After transport good 29 has been placed on secondary component 7 (which could be checked by a sensor) it begins to move in conveyance direction 34 indicated in the drawing, the package being delivered to the second conveyor belt 24b, which in turn removes transport goods 29. A positioner 28 having a telescope-type plunger and/or piston/cylinder unit pushes transport good 29 from secondary component 7 onto conveyor belt 24b for this purpose, once again with the aid of transport rollers 25. In this example, path 21 configured according to the present invention is used to synchronize two conveyor belts having different

conveyance speeds. It is only the design approach according to the present invention that allows the high acceleration and braking operations required to realize such a synchronization.

In the previous example, path 21 was formed in the horizontal plane. However, for other application purposes, it is also possible to define the path in the vertical plane, for instance in order to realize a VFFS (vertical form fill and seal) machine. Any combination of two, three or more identical or also different paths 29 is conceivable. A slanted installation is possible as well, for instance in order to compensate for differences in height. Even a Möbius strip conveyor belt for the conveying and/or simultaneous rotation of transport goods 29 about a specific angle could be realized. In summary, the concept of the present invention provides the basis for a multitude of possible applications in the automation and packaging industries and for realizing many systems or solving many problems already known from the related art. Additional examples are the packaging of boxes, filling of containers, sorting of objects, folding of boxes, among many others.

Figure 5 shows a schematic, cross-sectional view of one possible way of supporting secondary component 7 on primary component 8, which is designed as track (section A-A, Figure 4). Shown are secondary component 7 and primary component 8 as well as rollers 37, balls 36 behind the rollers, and guide grooves along tracks 8. The rollers and balls for guiding secondary component 7 engage with these grooves. This could be a combination of roller and ball guides known from the related art, for instance from the product assortment offered by Bosch Rexroth Linear Motion and Assembly Technologies. By tapering width b of the path sections in curved regions, for instance, a rapid and even movement in transition 33 (Fig. 4) from a straight to a curved path section could be ensured.

While the rigidity is reduced by the tapering and the play of the system is slightly increased in these areas, this is negligible in practice, since the required precision in the movement is usually limited to the straight path sections.

A pure roller guidance would be conceivable as well. Such guidance systems have been developed specifically for the handling and automation technologies.

Ball-track guideways, which could theoretically be used as well, are characterized by high carrying capacity and high rigidity in all categories of precision and are suitable for virtually all tasks in connection with precise linear movements. Roller-track guides, due to the design-related rigidity, would allow even the heaviest loads to be moved with very little effort and with the degree of precision demanded by users of high-capacity tool machinery and robots. The roller-supported linear guideways are available in different classes of accuracy. They are characterized by high tolerated speeds, compact design, very low weight, simple installation and low friction. The extremely low-noise travel could be a factor as well.

Using a combination of ball rollers and a profile rail to accommodate ball rollers on the top and bottom sides (such as from Bosch Rexroth Linear Motion and Assembly Technologies), secondary components 7 could be moved easily and steered via primary components 8. Secondary components 7 would then have to be provided with spherical indentations to accommodate the balls. Ball rollers have an excellent track record as components in feeding systems and conveyors on processing machines and packaging systems. Supplementary rails could be used when there are higher demands on the movement precision.

Naturally, additional methods for configuring the path sections known from linear technology are conceivable. One skilled in the art should consult the available documents in this context, which are numerous without a doubt. However, the design approaches must be analyzed with respect to their suitability for the application-specific demands. In the example shown, such demands would be relatively high due to accelerations of up to 15 g, speeds of up to 5 m/s and positional accuracy in the range of a few micrometers. Metals such as steel or aluminum are suitable as would be plastic.

List of reference numerals

1	setpoint interface
2	air gap with traveling field
3	energy interface
4	sensor interface
5	control interface
6	signal-processing device
7	secondary component
8	primary component
9	coil controller
10	field-generating coils
11	energy source
12	movement-state sensor
13	control connection
14	half-bridge
15	PWM control
16	comparator
17	actual-value generator
18	supply voltage having polarity a
19	supply voltage having polarity b
20	mass
21	path
22	path section
23	measuring device
24	conveyor belt
24	conveyor
24b	removal conveyor
25	conveyor rollers
26	central control unit
27	drive
28	positioner
29	goods to be conveyed
30	industrial machine
31	curve module
32	straight module

33 transition

34 conveyance direction

35 data bus

36 ball

37 roller